Los Alamos Updates to nuclear data evaluations

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Overview:

- ✓ Light element evaluations
- ✓ ^{208}Pb evaluation
- ✓ Minor actinide evaluations
- ✓ Summary

LANL Light-element (LE) evaluations

- Multichannel, unitary: fit all reaction/scattering data simultaneously
- Fit *quantum mechanical amplitudes*, not cross sections
- Superior to single-channel & cross-section curve fitting
- High-fidelity, low chi-squared: χ^2/DOF ~ 1.2 – 1.5

Core capabilities/efforts

- LANL lead contributor LE evaluations for ENDF/B-VIII.0 (see table below)
- LE evaluations for many users/formats (ENDF, NJOY, ACE, NDI, etc.)
- Provide covariance information for all LE evaluations
- International efforts (IAEA Consultant's Meeting R-matrix evaluations/Standards)

Catalogue of some light-element evaluations

	H1	H2	H3	He3	He4	Li6	Li7
n	VIII.0	VII.1	VII.1	VII.1	VII.1	VIII.0	VII.1
p	VII.1	VII.1	VII.1	VII.1	2011*	VII.1	2001*
d		VII.1	VII.1, 2018	VII.1	2011	VII.1	2003*
t			VII.1	VII.1	2011*	VII.1	--*
^{3}He				2001	2011*	VII.1	--
α					2011*	--	--

NCSP evaluations of interest

- NN, ^{9}Be, $^{12/13}$C, ^{16}O

EDA Code Modernization

- ***NCSP FY20 request***
- Higher-energies (<20 MeV)
- Interface EDA & NJOY, etc.

Roman numerals refer to ENDF versions
-- All LANL evaluations except *
-- * denote LLNL evaluations

CoH_3: Coupled-Channes Hauser-Feshbach code

❑ Hauser-Feshbach-Moldauer therory for compound nucleus reaction

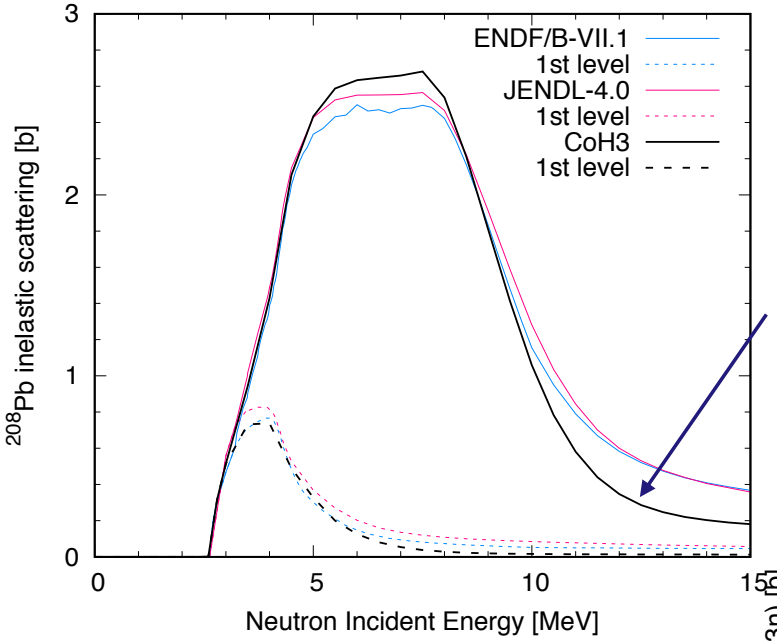
- 45,000 lines C++ code (~ 140 C++ source files, ~60 headers, ~80 classes)
- maintain by GNU Autotools package

❑ Modules and Models employed

- spherical and deformed optical models
- DWBA for direct inelastic scattering
- Moldauer's width fluctuation correction with LANL parametrization
- Gilbert-Cameron level density with updated parameters
- pre-equilibrium 2-component exciton model
- Madland-Nix prompt fission neutron spectrum including pre-fission emission
- direct/semidirect capture model
- mean-field models (FRDM and Hartree-Fock BCS)

Consistent evaluations in all channels

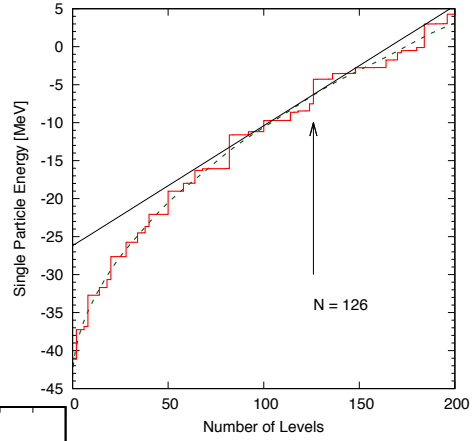
CoH_3 New Evaluation of ^{208}Pb, (n,n'), (n,2n), and (n,3n)

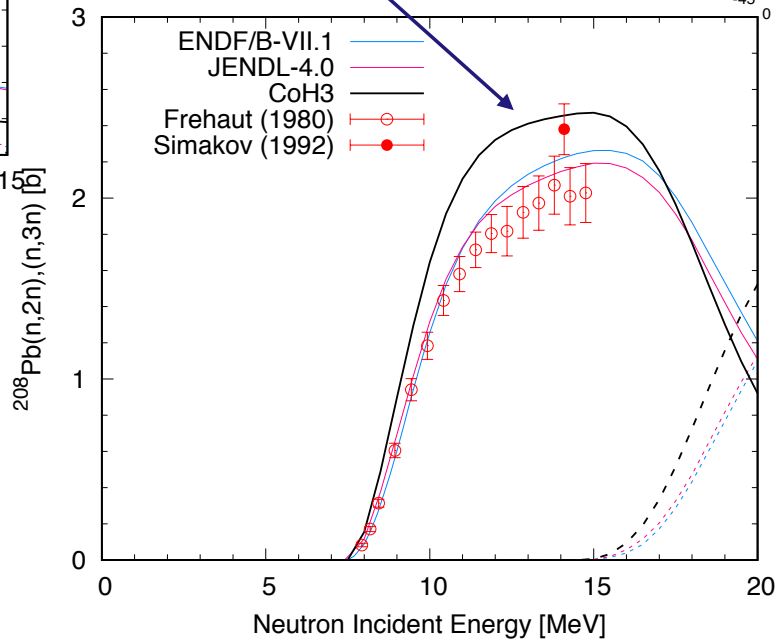


Pre-equilibrium estimated by the single-particle model based on FRDM

Strutinsky shell correction predicts lower single-particle level density

- lowers the pre-equilibrium emission
- increase (n,2n)

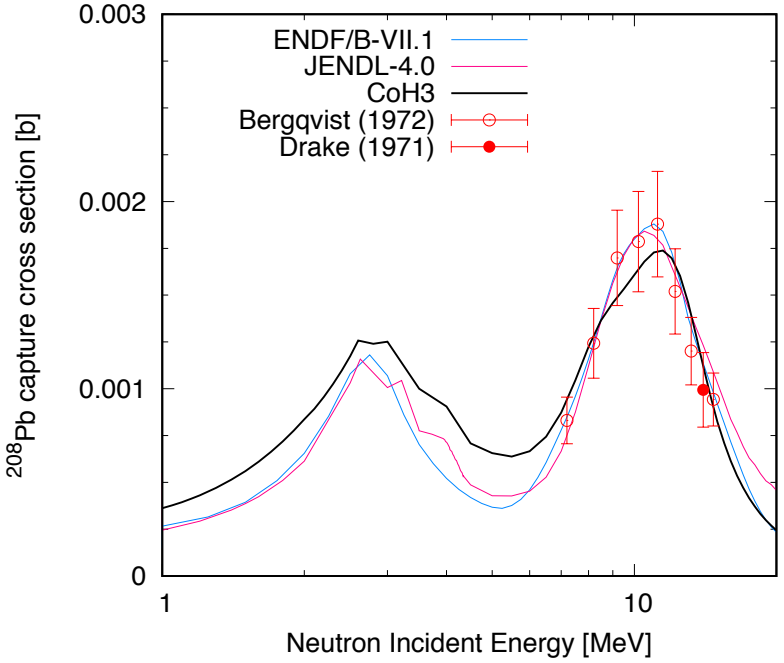


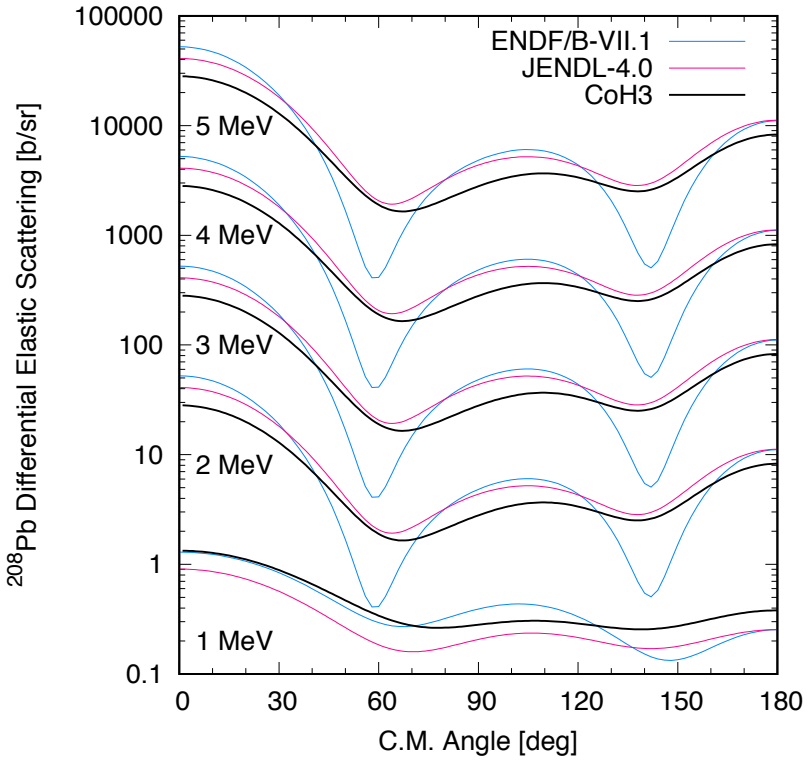


New evaluation better agrees Simakov data

Need to re-investigate if Frehaut data should be renormalized

CoH_3 New Evaluation of ^{208}Pb, Capture and Elastic



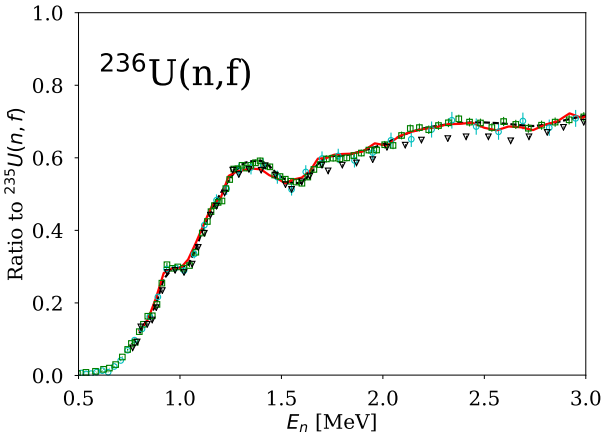


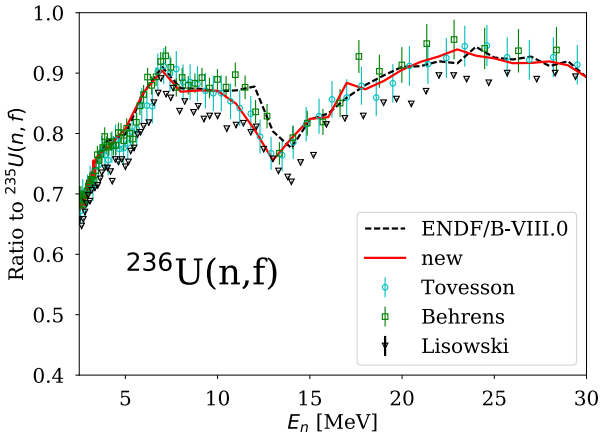
Very small capture cross section
Realistic Direct/Semidirect capture theory applied
(evaluations are simple Lorentzians)

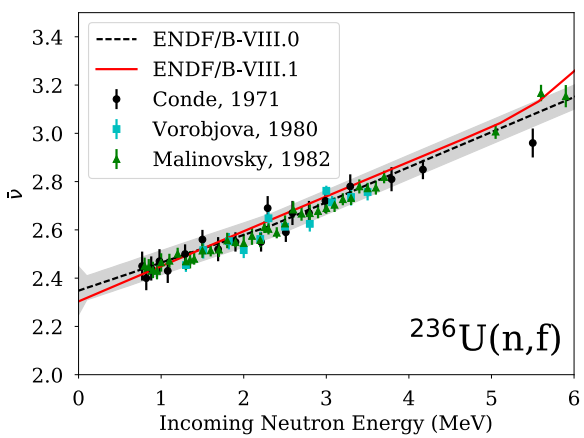
Unphysical dips near 60 and 140 degrees removed
Evaluation similar to JENDL-4

Evaluation of ^{234,236}U

- **Extensive and consistent** evaluations based on CoH3 calculations, with parameters adjusted to experimental data (DANCE, WNR)
- All open channels included
- KALMAN-based evaluation for fission channel to include cross section data from WNR
- ^{234}U: re-evaluation of nubar, consistent PFNS
- ^{236}U: re-evaluation of nubar above 2nd chance fission, PFNS
- PFGS and gamma multiplicity taken from the recent ^{235}U evaluation

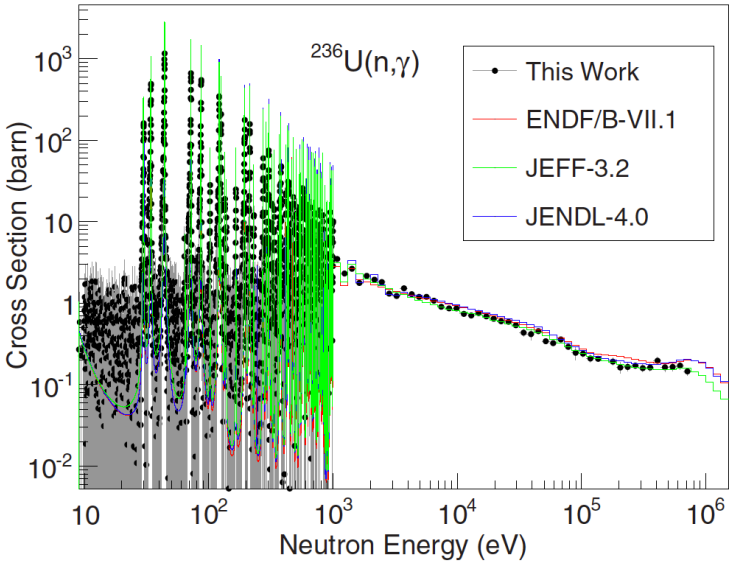




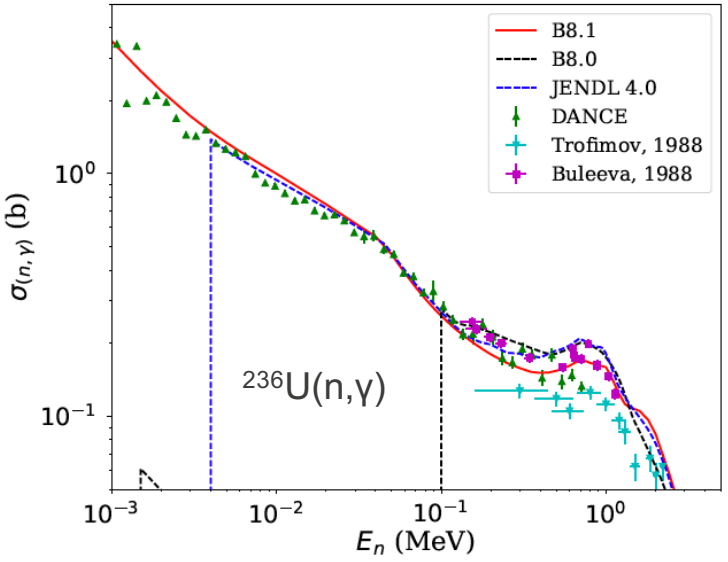


Evaluation ^{234,236}U (capture)

- Resonance parameters for ^{236}U(n,γ) refitted to DANCE data, but only for the s wave and in different format than currently in ENDF (new fit this summer?)
- Data for ^{234}U(n,γ) will be analyzed this summer (before September?)
- CoH_3 evaluation
  - Width corrections fluctuation of Moldauer, with the Engelbrecht-Weidenmüller transformation (strict treatment of the directly coupled channels in the Hauser–Feshbach theory), the coupled-channels optical potential of Soukhovitskii
  - Same parameters used for the suite of U isotopes

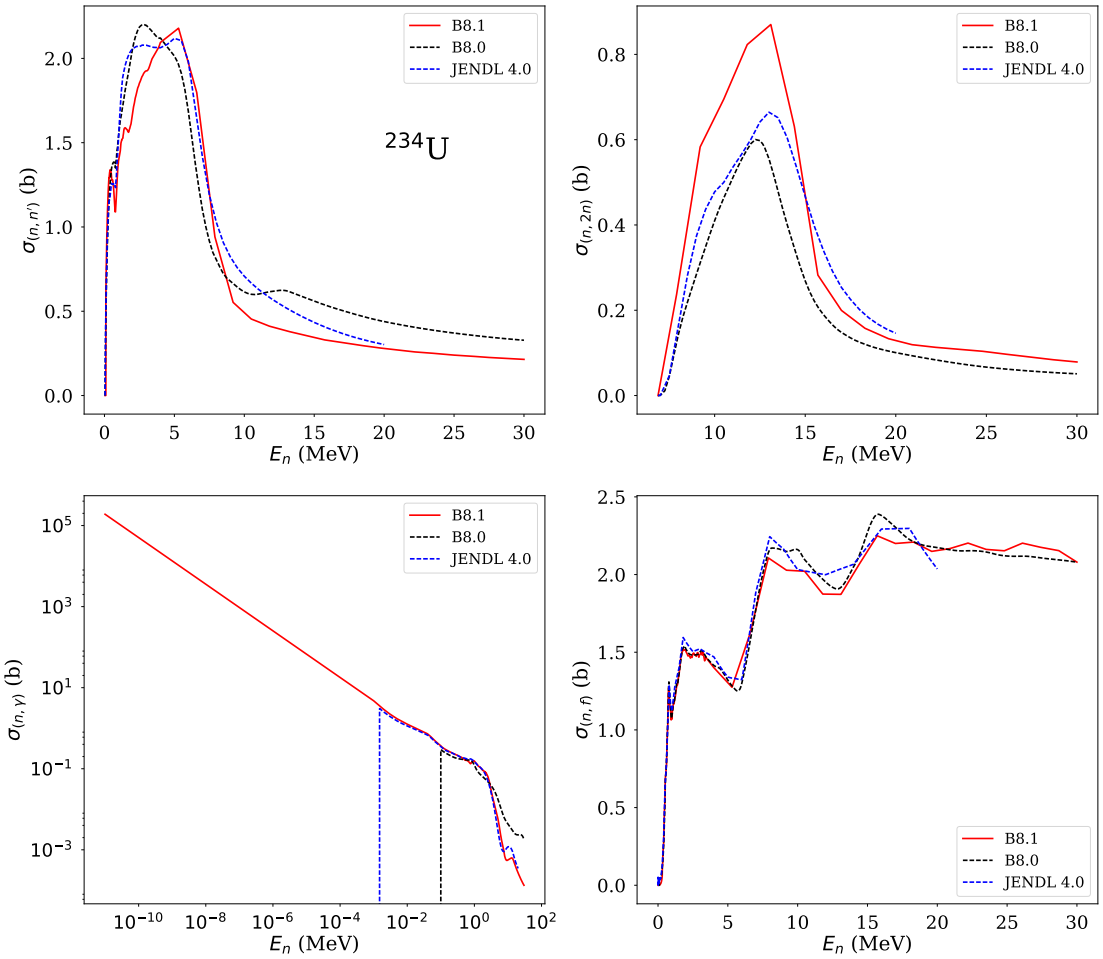


Baramsai et al, PRC **96** (2017) 024619



CoH_3 evaluation

^{234}U evaluation: all channels consistent from CoH_3 calculations



New paradigm for nuclear data evaluations

- **Novelty in evaluation procedure**:
  - Include >1000 integral experiments of various types
  - Develop infrastructure for re-adjustment of existing evaluations each time any evaluation is changed

- **Prerequisites**
  - Reliable set of integral experiments (with input decks)
  - Library of inputs and scripted procedures allowing for quick re-evaluation
  - ML techniques for tracing outliers (in experiments and evaluations), for performing global adjustment and analysis of the results
  - Reaction modeling adequate to reproduce experimental data (all reaction mechanisms)
  - Extensive set of sensitivities
  - Automated validation
  - Integration of experimental, evaluation and validation communities

- **Benefits**
  - Accounting for differential and integral exp. on the same footing
  - Extensive set of covariances including cross-material correlations
  - Reduction of error compensation
  - Improved responsiveness to new measurements and model advances

Summary

- Extend light-element evaluations: higher energy via code modernization
- Improved evaluation for ^{208}Pb
- Complete and consistent evaluations for ^{234,236}U
- CoH3: extensive (many models) and flexible evaluation tool neutron induced reactions on medium and heavy nuclei
- New evaluation scheme using ML algorithms

Work in progress:

- Identify benchmarks that include ^{234}U/^{236}U and check the performance of the evaluation
- Include the s-wave parameters for ^{236}U(n,γ) (DANCE)
- Compare with ^{234}U(n,γ) cross section, when the analysis is finished
- Neudecker: updates of PFNS for U and Pu based on new ChiNu data
- Kawano, Stetcu, Talou: new deterministic Hauser-Feschbach cascade model for PFNS/PFGS
- Adjustments to CGMF parameters so it can be used in future evaluations